Lightning Protection

The annual toll of damage and loss from lightning is over $40 million. Over 20,000 fires are caused each year by lightning bolts. Much of this damage is the result of direct hits, either to a building or to the electrical lines near the service entrance. Other damage is the result of lightning-induced surges on power lines, antennas, and conductors in the vicinity.

Spare the rod?

A common sight on the rooftops of American homes just a few years ago was the lightning rod. It symbolized the respect that mere mortal homeowners had for the awesome power of lightning. Today, a drive through suburbia reveals that the lightning rod has faded from the scene. Unfortunately, lightning has *not*.

The popularity of the ground-plane antenna has produced a new substitute for the lightning rod. Few consider it as more than a radiator of rf energy, but when installed on a roof, the vertical ground-plane antenna serves as a likely target for a bolt from the not-so-blue sky. When well-grounded, the ground-plane antenna can serve to divert a surge from seeking a lower point on the roof.

There is ample information today on how we can protect against the real zapping of America. Prudent people — ham radio operators in particular — can take steps to protect

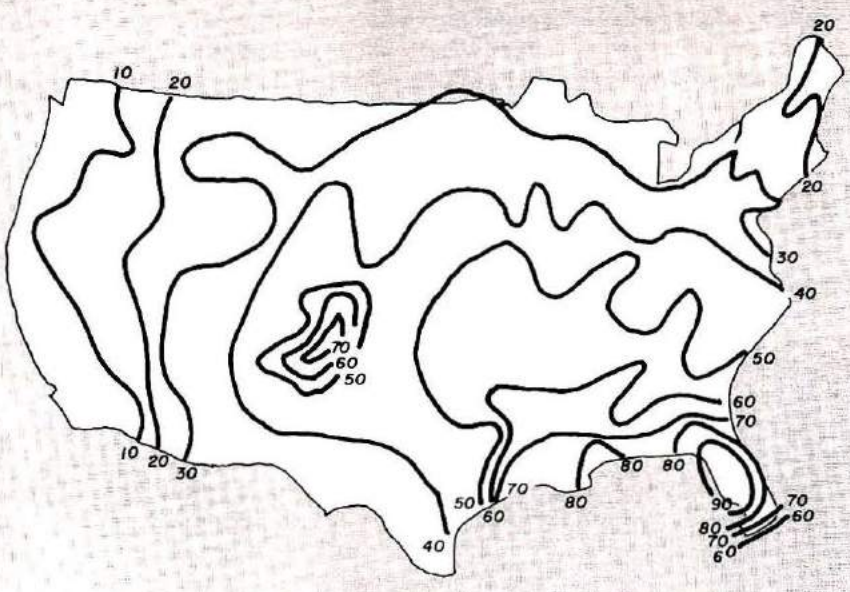


Fig. 1. Average thunderstorm days in the United States.

Table 1. Lightning-damage probability. Source: Rural Electrification Administration study of February, 1977.

Geog. area	Earth Res. zm	Storm days per year	"Fig. of Merit"	Lightning Damage Probability
NW FL	1,000	80	11,520	Very high
NE GA	1,000	55	6,655	
SW FL	250	110	4,840	
C CO	500	60	4,140	
NE WS	500	52	2,974	
E TN	500	50	2,875	– 2900 High
C WV	500	45	2,531	
C ME	1,000	25	1,938	
W TN	250	53	1,615	
SE AZ	250	50	1,375	
NW MS	125	52	743	– 1000 Average
NW NY	250	30	675	
E NV	250	30	630	
C UT	125	40	520	
NW MN	125	35	475	
C OK	67	53	433	
C IL	67	50	419	
C NM	67	50	385	
S ME	500	15	382	
C LA	67	45	353	
SW KA	67	45	339	
NE TX	67	47	325	
W NV	250	18	243	
SE TX	33	55	200	– 200 Low
C KA	33	50	198	
C MT	67	30	187	
W KA	33	45	167	
C ND	33	33	111	
W VA	500	7	93	
W CA	125	5	11	– 80 Very low

themselves and their property. The latter most emphatically includes our expensive radio gear!

A good lightning protection system for the Radio Amateur would cover three major areas: grounding of radio equipment and antennas, avoiding easy entry of lightning charges via the electrical service entrance, and proper installation of a good ground system.

The accepted standard for lightning and fire protection is the National Electrical Code adopted by the National Fire Protection Association (NFPA). Installations made in conformance with this code will assure the Radio Amateur little grief with the law or insurance adjusters, should a claim arise.

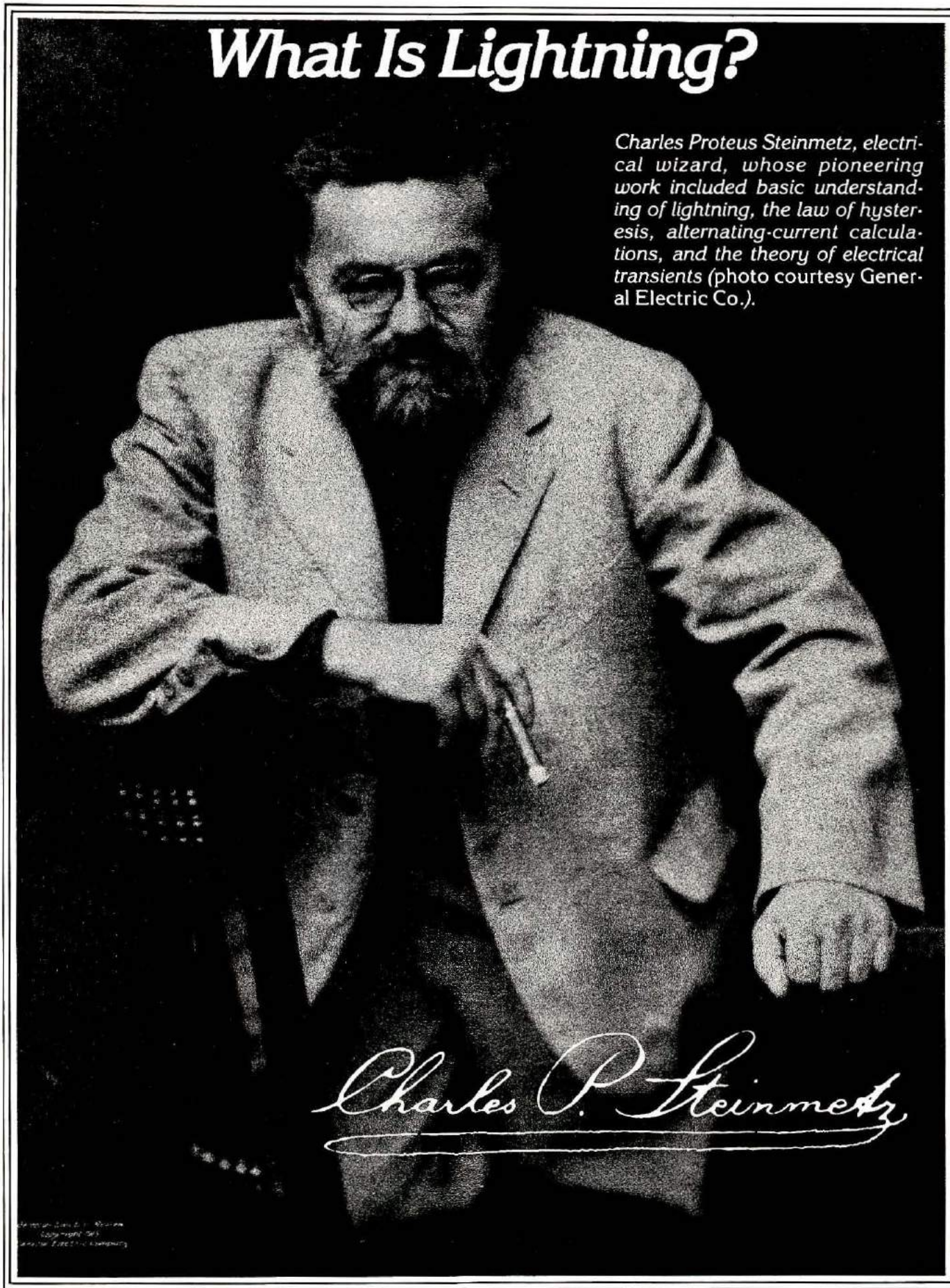
Part of the NFPA code deals with radio and television equipment. For example, outdoor antennas and feedlines running to a building shall not cross over electric light or power circuits, and should be kept well away from all such circuits so as to avoid possible contact. Masts and metal structures supporting antennas shall be permanently and effectively grounded, without intervening splice or connection. Each conductor or lead-in to radio transmitters shall be provided with a lightning arrestor, or other suitable means, that will drain static charges from the antenna system.

AC lines

One of the easiest ways for a lightning surge to enter your home and radio shack is the main ac power line. Some induced surges can be several volts in amplitude and be sufficiently high to burn out or harm any electrical device plugged into the household lines. The accepted practice is to allow surges on the incoming service line to be bypassed to ground by means of a lightning protector installed at the service entrance. A typical unit is the GE TLP175, a Thyrite® disc type that will perform its protective function repeatedly without maintenance, see photographs.

Since other spikes on the ac line can be induced by surges *inside* the home due to inductive "kicks" from solenoids, motors, or the switching on or off of an appliance, protective devices may be installed at the ac input of radio equipment, TV receivers, and other solid-state devices. The va-

What Is Lightning?



Charles Proteus Steinmetz, electrical wizard, whose pioneering work included basic understanding of lightning, the law of hysteresis, alternating-current calculations, and the theory of electrical transients (photo courtesy General Electric Co.).

Different Strokes

Until Ben Franklin's famous kite-flying experiments in 1752, thunder and lightning carried mysterious significance. Ancients gazed skyward at the thundering clouds, imploring Zeus and his bolt-hammering associate, Vulcan, to spare them another hair-raising experience.

While Ben's observations first identified lightning as electricity, it escaped serious study until early in this century. Then, a very large intellect, carried in a small body belonging to Charles Proteus Steinmetz, began laboratory experiments that quantified lightning and helped man understand the means needed to tame it.

Steinmetz was a tireless experimenter who frequently worked long into the evening, at his Schenectady, New York, home, on arc-light electrodes. The flashing blue lights undoubtedly attracted the attention of neighbors, who observed the electrical wizard's bearded chin, ever-present cigar — and fondness for unusual pets such as Gila monsters and alligators — and undoubtedly branded him eccentric. Yet, Steinmetz was the first to make key observations on the protection of electric-power transmission systems. He was called, "the man who tamed lightning."

From such experimental work unfolded an understanding of the anatomy of lightning. Sensitive instruments measured it, and the high-speed, rotating-lens camera showed it to be a complex phenomenon of many components rather than a single bolt.

By definition, lightning is a gigantic electrical spark, resulting from millions of volts and thousands of amperes hurtling between clouds and earth, and produced by the attraction between positive and negative electric charges.

Lightning is accompanied by thunderstorms which develop with the formation of massive clouds and rapid updrafts of moist air rising by convection from a hot, humid area. Within this major upheaval are produced charges of hundreds of millions of volts, adequate to produce lightning strokes from cloud to earth, or among clouds. Separation of charges and resulting voltage buildup can be rapid as evidenced by the number of strokes occurring while a storm passes over an area.

Lightning bolts descend from the sky in a series of successive, hesitating steps. Total time for this zig-zag route may be as much as 1/150th of a second.

Stroke voltages may start at hundreds of millions of volts between cloud and earth, but when the bolt hits earth, mutualization of charges somewhat reduces the voltage. However, millions of volts can still be delivered to the building, tree, power line, or antenna which is struck. Actual voltage depends upon the amount of current, conductivity of the struck object and impedance of the path to true ground.

Depending upon the violence of the storm, the stroke current may range between 1,000 and 200,000 amperes. Stroke current flows through the leading node of a bolt, and usually builds to a peak within one to ten microseconds after the bolt completes contact with the earth.

About half of the lightning strokes are multiple, with from 2 to as many as 42 individual strokes. They're caused by quick recharging of the cloud area and may last for as long as 1.5 seconds, with cumulative energy and destructive force also multiplied.

When a stroke is about to take place, the surrounding surface of the ground for a radius of several miles carries an electrical charge. As the lightning stroke takes place, this surface charge moves radially toward the ground end of the air path, forming an electric current in the ground. At the point where the discharge enters the ground, the current density becomes high. If the flow takes place through a foundation wall, such as your shack, damage is likely.

In view of this, ground systems should be distributed rather symmetrically outside and around the circumference of your house and shack rather than grouped on one side. With ground connections properly distributed, the current will be collected at the outer extremities, with the flow underneath your home minimized. At least two ground connections should be made at opposite sides of your house.

Lightning Protection

Charles Proteus Steinmetz, left, "the man who tamed lightning," in 1922 demonstrated his artificial lightning generator to Thomas A. Edison in Schenectady, New York (photo courtesy General Electric Co.).

ristor is one electronic device that chops off surges at 600 volts, protecting the circuits beyond.

Like the ac line, any conductor entering a home or ham shack supplies easy entry for lightning surges. Therefore, the best protection is to completely disconnect all equipment from antennas and eliminate all paths for strokes. Rotator cables are frequently overlooked, but should be disconnected during electrical storms.

Transmission lines

Any lightning surge that hits your antenna feedline will follow it into your shack unless it is bypassed to ground *outside* your dwelling. Some commercial devices are available that can be inserted in the coaxial line — the "Blitz bug" and Hy-Gain's LA-1 and LA-2 are examples — and when connected to ground will provide some protection.

Installing your feedlines so that they enter your shack via SO-239 chassis fittings mounted on the outside wall allows rapid disconnections when your station isn't in use.

For open-wire feedlines, a simple lightning arrestor can be made with copper or brass strap mounted on three stand-off insulators. A spark gap between the two conductors is connected to ground, adjusted so that it doesn't arc at the highest power level operated, see **Fig. 2**.

Long wires, with the antenna running directly to the transmitter, are a particularly dangerous lightning path. Either the conductor should be disconnected completely or an outside spark gap should be mounted at the point of entry into the shack wall.

Any feedlines that are grounded *inside* your shack will allow voltage spikes and surges to gain entry, and should be considered risks of fire or damage to your radio equipment.

There are many coaxial switches sold that offer automatic grounding of antennas when not in use, and antenna tuners that are equipped with a "lightning protect" position, but both allow lightning to come inside your shack. They will protect against static buildup on the antenna system, but any solid hit will carry high currents ample to cook wafer switches, and most coaxial switches as well.

The best protection is to keep lightning *outside* your shack!

Equally important is disconnecting the ac lines from your radio gear when not in use and when thunderstorms are most likely.

Ground wires

The conductor used for grounding connections should be equivalent in strength and cross-sectional area to a No. 6 AWG (4 mm) copper wire. Solid wire is ideal.

If aluminum wire is used for a ground conductor, it should not be used in conjunction with copper, copper-covered, or copper-alloy fixtures.

Materials used for the ground system should be resistant to corrosion, according to the NFPA code. No combination of materials should be used that forms an electrolytic couple so that corrosion is accelerated in the presence of moisture.

Ideal ground rods are from six to ten feet long, and are usually made of solid copper, copper-clad pipe, galvanized pipe or galvanized iron rod.

The ground system

A good ground system is easily made in areas where the soil has low resistance — moist soils near salt water are ideal — but will require more effort if rocky, dry conditions prevail.

Properly made ground connections are essential to a well-functioning system, and every effort should be made to provide ample contact with the earth. Where good, moist soil exists, a ground rod ten feet into the ground will provide a resistance of from 20 to 50 ohms, and two such rods connected together, one at each end of a house, will be adequate for collecting and dissipating the energy of a flash.

If your soil is rocky, as it is here in Connecticut, conventional grounding methods will be difficult. Most kinds of rocks are insulators, or at least of high resistivity, so to obtain an effective ground, an extensive network of wires can be laid on the surface of the rock — much like an antenna counterpoise — or pushed into slits cut in the soil to cover the wires and avoid the hazard of tripping passers-by.

Such a wire web will include areas where the resistance to earth is high, but at the same time the potential dis-

tribution around the house is substantially the same as though it were resting on conducting ground, and the protection resulting is also about the same.

One technique used by hams with dry, rocky soil is to add salt to the soil surrounding a ground rod. If a post-hole digger is available, the rod can be inserted after a hole is cleared of rocks and gravel and filled with a mixture of commercial salt and topsoil. Try to avoid getting the salt near the surface, or grass will have a hard time sprouting. Putting a ground rod near drains or downspouts will work, as they help keep the soil moist.

It's recommended that all ground systems in the house be bonded together. The copper or lead water pipes, and telephone ground wire, should be included, together with the ground of the electric service. Common bonding is recognized as the most effective method of preventing side flashes resulting from a lightning discharge.

Conductors should be installed with consideration for offering the least impedance to the passage of stroke current between the air terminals and ground. The most direct path is best, and there should be no sharp bends or narrow loops for the lightning to jump across on the ground. The impedance to ground is almost inversely proportional to the number of widely separated paths, so from each roof- or tower-mounted air terminal there should be at least two paths to ground.

Towers and masts

By their nature, towers and vertical structures are ideal "targets" for lightning and should be well grounded. The tower and its guys should be connected to the main ground system, and a separate ground rod should be installed near the base of the tower. A radial system of ground wires extending away from the tower base is effective, and each wire should have an individual ground rod connected at its end. If these radials are cut for one-quarter wavelength, they will naturally serve as rf grounds should the tower be shunt fed and used as a vertical antenna. The radials should be spaced about ten feet apart at their ends, and the main tower ground rod should *not* run through the concrete base if one is used to support the tower. The reason is that with a direct strike, the high current would likely heat the base material and cause it to explode.

An rf ground and a lightning ground may not be the same, as many apartment-dwelling hams have discovered. If the radio shack is located several floors up, the ground wire may become resonant on several bands and lose its effectiveness for rf purposes. One solution is to add quarter-wave resonant lengths.

Boats

For Radio Amateurs operating maritime mobile, the installation of antennas on the mast is a common procedure. In such cases, the radio antenna may serve as a lightning-protective mast provided it has adequate conductivity and is equipped with lightning arresters, lightning-protective gaps, or a means of grounding during electrical storms.

Obviously, materials used for grounding systems on boats should be resistant to corrosion. Avoid using combinations of metals that form galvanic or electrolytic couples. Number 8 AWG (3.3 mm) copper is recommended.

If a vertical antenna is used that has a loading coil at the base, consider the antenna as ending immediately below the coil. A suitable gap should be provided for by-passing lightning current.

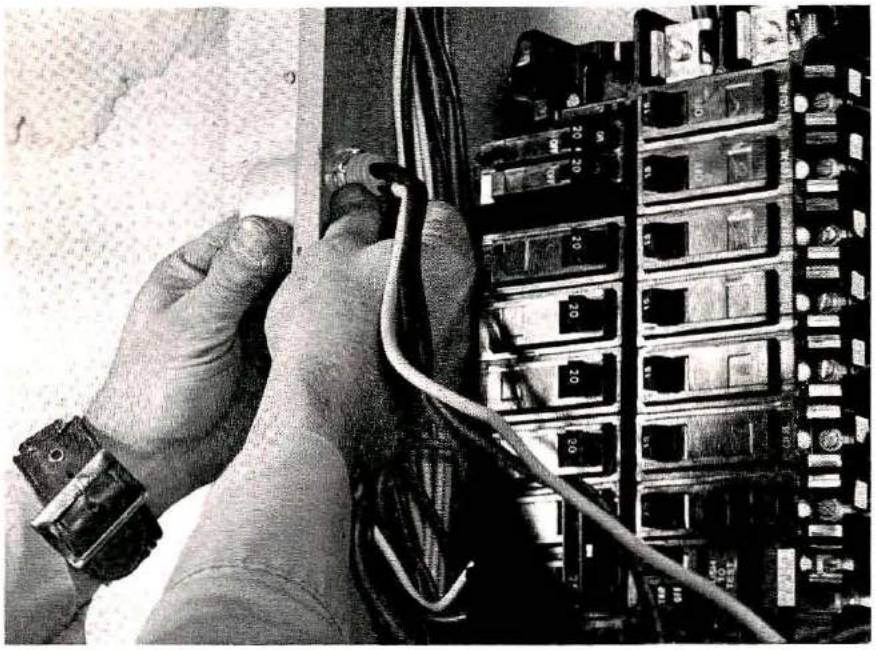
A current connection for a boat consists of any metal surface normally submerged in the water and that has an area of at least one square foot; propellers and metallic rudders may be used. A steel hull also provides an adequate ground.

Protecting lives

Most of our discussion has involved the protection of property — including our radio equipment. But please remember that simple safety precautions can also help protect lives against severe injury or death due to lethal strikes or high-voltage shock.

The lightning hazard is greatest among those who are outdoors a great deal. For those who are inside buildings during electrical storms, the risk is far less and serious injuries are

To operate General Electric's new Voltage Spike Protector (VSP), simply plug the VSP into any 120-volt grounded alternating current (ac) receptacle, and then plug the cord from your TV set, radio, or stereo into the VSP (photo courtesy General Electric Co.).



A home lightning protector installed on the main ac service entrance will bypass lightning surges to ground and guard appliances and radio equipment plugged into the ac system (photos courtesy General Electric Co.).

rare. It has been said many times that to seek shelter from an electrical storm by standing under a tree is a mistake, and an invitation to a lightning strike. Working around towers, masts, and various antennas with a thunderstorm approaching is also a bad bet. Avoid the high ground and any conductor that could suddenly get "hot" in the event of a strong buildup of electrical potential.

Seek shelter in one of these places if possible: large metal-frame buildings, homes that have lightning protection, automobiles or buses with metal tops and bodies, trains, trailers with metal bodies, enclosed metal boats or ships, or on city streets that are shielded by nearby buildings.

In heavily urbanized, built-up towns and cities, the hazard isn't as great as in the open country. Barns and other large, isolated buildings are the most prominent targets for lightning in a large open area. In hilly or mountainous districts, a building on high ground is usually subject to a greater hazard than one in a valley or otherwise sheltered area.

During an electrical storm, be sure to remind other members of the family to stay away from electrical appliances or plumbing fixtures such as faucets, etc. Taking a shower or bath during an electrical storm is ill-advised, since a lightning strike in the neighborhood could send severe high-voltage surges through the ground, and the surges can travel along conducting pipes. Pulling the plug on the family TV set is also a good idea, although the kiddies in the household might stage an instant protest.

Every ham shack should have a fire extinguisher handy, and additional units should be mounted conveniently on each floor. The rating should be such that the contents are effective against *electrical* fires in particular.

First aid

What do you do in the event someone is shocked by a lightning-induced surge or an electrical short circuit? Follow the basic rules of first aid for an electrical emergency.

If the victim is in contact with *live* electricity, first shut off power. If this isn't possible, call the power company. An alternative is to free the victim from the "hot" wire or appliance using either a dry rope, dry board, or dry stick, making sure that your hands are dry and that you're standing on a dry surface.

Then, treat for asphyxiation. Use the standard methods of mouth-to-mouth, or the modern cardiopulmonary resuscitation (CPR) technique of artificial respiration.

For shock, get medical aid as soon as possible, and in the meantime keep the victim warm, placing the head lower than the feet. If the person is conscious, give fluids unless the victim is nauseated or has a penetrating abdominal wound.

If the victim has burns, cut away loose clothing, cover the burned area, and around it, with sterile dressings to keep out air.

Conclusion

Lightning is a serious business, but it need not cause you to give up a wonderful hobby, or to lose a lot of gear for lack of protection. Provide low-resistance paths, in several directions, outside your shack to encourage lightning to take the shortest route. Hook some protective devices across the ac line to suppress spikes and surges, and then disconnect your lead-in wires when things really start grumbling. You'll sleep a lot easier and still have a rig for tomorrow morning's DX search.

HRH